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(71) Applicant(s)

Telia AB

(Incorporated in Sweden)

Marbackagatan 11, S-123 86, FARSTA, Sweden

(72) Inventor(s)

Eric Wichtel

(74) Agent and/or Address for Service

Ronald Nicholson

N&M Consultancy Limited, 4 Pine Grove,  
BISHOP'S STORTFORD, Herts, CM23 5NP,  
United Kingdom

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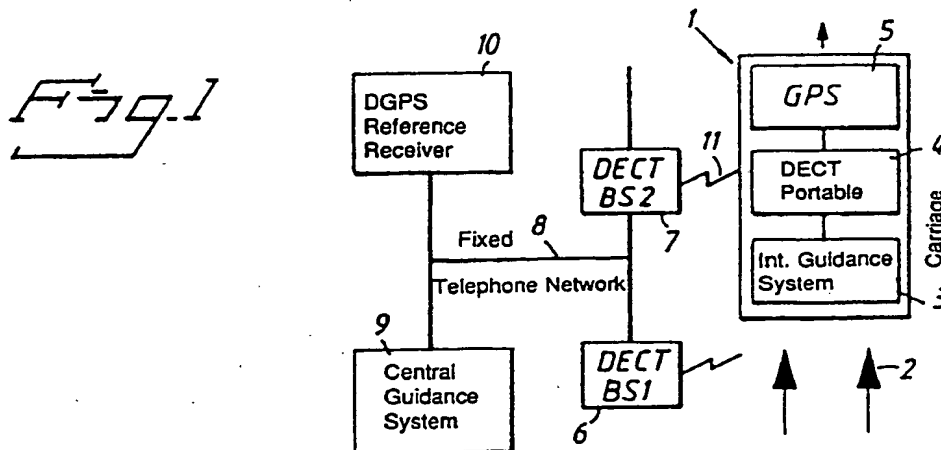
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## (54) Railway communication and positioning system

(57) A possibly driverless railway vehicle 1 comprises a GPS receiver 5 and a communications terminal 4. Along the side of the track are regularly spaced communications base stations 6, 7 etc. A fixed GPS receiver 10 determines DGPS corrections and transmits these via telephone network 8 and a base station 6 or 7 to the train 1. When the train is underground (eg in a subway (12, fig 2)) an inertial guidance system 3 and/or a laser transmitter/receiver system (17, 18, 19 fig 3) using reflectors (20, 21, 22) mounted on the subway wall provides the positional information. Telephonic communication is also possible.



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Fig. 1

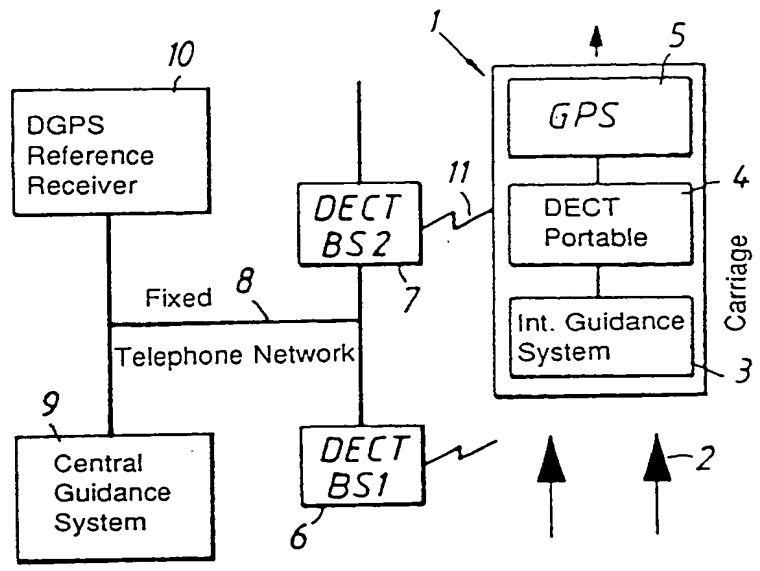


Fig. 2

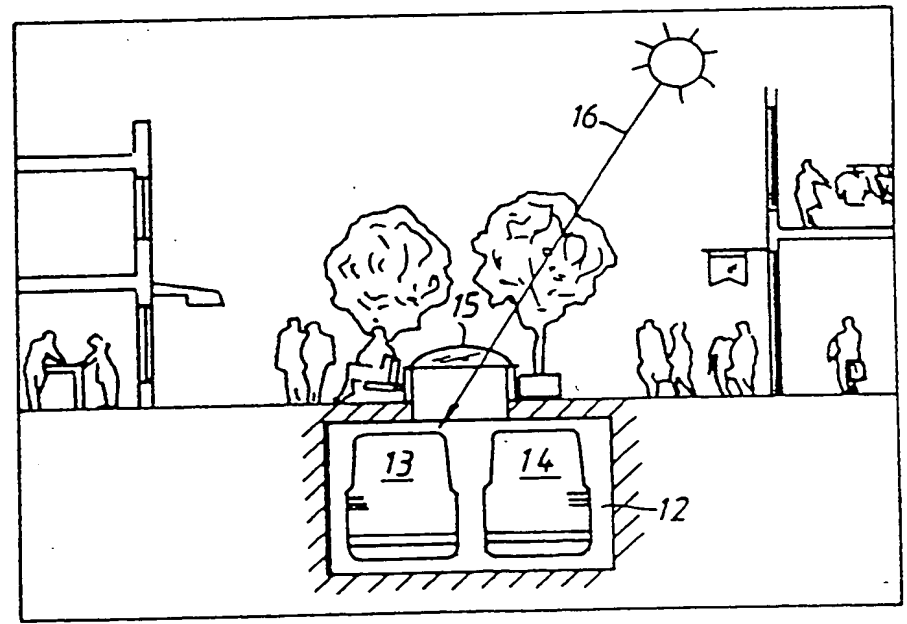
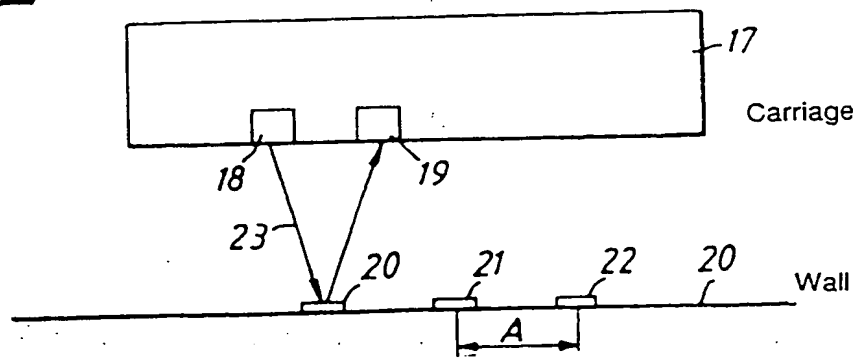


Fig. 3



A COMMUNICATION AND POSITIONING SYSTEM FOR USE IN A  
TRACKED TRANSPORTATION SYSTEM

5       The invention relates to a communication and positioning system for use in a tracked transportation system having a plurality of mobile units, for example, carriages, or the like, arranged to move along a track system.

10       At the present time, the cost of known guidance systems for tracked transportation systems for collective traffic, is estimated to be of the order of 10 million Swedish crowns per kilometre. Also, the wages of the drivers of the mobile units for such systems are estimated to be more than half of the operating costs of the system.

15       There is, therefore, a need for a communication and positioning system for use in a tracked transportation system which will make it possible to have driverless mobile units. In this regard, it has previously been suggested that a system of this type could be provided by means of a data bus, installed along the length of the track, and used in association with a number of two-way short-range communication units spaced-apart, about 1/m, along the length of the track. With such a system, the intention is to provide identity and certain logic information at distances of one decimeter. A respective mobile unit, or carriage, is thus positioned every metre along the length of the track and is given certain capabilities for communicating.

25       Existing solutions for communication and positioning systems for use in a tracked transportation system are relatively primitive. There is at least two known types of system. One of the known systems operates with fixed

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blocks and the other one of the known systems operates with moving blocks.

5 With the fixed block system, the track is divided up into a number of sections, and only one train unit is allowed in a track section, at any one time. A collector shoe which short circuits two metal rails constitutes a detector. Such systems are currently available on the market. With the moving block system, a train unit is surrounded by a safety area within which no other trains  
10 are allowed.

15 An object of the present invention is to provide, in a technically and/or economically more advantageous manner than has hitherto been the case, a communication and positioning system for use in a tracked transportation system. In addition, such a system will have the capability of accurately positioning each of the mobile units in the track system and will provide general data communication between the mobile units and the infrastructure.

20 The invention provides a communication and positioning system for use in a tracked transportation system having a plurality of mobile units arranged to move along a track system including a plurality of base stations located at regular intervals along the length of the track system and  
25 adapted to communicate with each of the mobile units; reference positioning means for providing a reference for establishing the position of each of the mobile units in the track system; on-board positioning means for each of the mobile units, adapted to establish the position of the  
30 respective mobile unit in the track system; on-board communication means for each of the mobile units, adapted to communicate with each of the base stations, on passage

of the mobile unit past a respective base station; and telecommunication means for connecting each of the base stations to the reference positioning means, wherein the on-board positioning means of a mobile unit are up-dated by the reference positioning means when the mobile unit passes a respective base station, and wherein the said up-dating of the on-board positioning means is effected via the telecommunication means.

The communication and positioning system according to the present invention is adapted to be implemented within the short term and utilises a technical design which is relatively simple to implement and which is relatively inexpensive to manufacture. In addition, the mobile units, or carriages, are preferably driverless and, as a consequence of this, the reliability of the system is relatively high.

The accuracy of the positioning function of the system according to the present invention is much greater than the accuracy of known systems and is of the order of approximately one metre.

Furthermore, accurate positioning of the mobile units can be effected in a continuous manner and even smaller train units, for example, carriages, can be driven at closer intervals, i.e. the separation distance between the mobile units can be minimised.

According to one aspect of the present invention, the communication and positioning control functions of the system are effected separately, the communication function being effected via the base stations and the positioning function being effected by a radio communication system, preferably of a type known as DECT (Digital European

Cordless Telecommunications).

5       With track systems which include track sections that  
are either totally open, or partially covered, or  
relatively long, the communication and positioning system  
according to the present invention includes a reference  
10       positioning means, in the form of a calibrated Global  
Position System (GPS) reference station, that is adapted to  
calculate corrections for differential GPS, and the on-  
board positioning means of each of the mobile units include  
15       a mobile GPS receiver that is adapted to calculate the  
position of the respective mobile unit in the track system,  
the calculated position of a respective mobile unit being  
corrected by data from the fixed calibrated GPS reference  
station to provide a higher positional accuracy than is  
20       attainable with the on-board positioning means alone. The  
accuracy of the calculation of the position of a mobile  
unit by the on-board positioning means is of the order of  
100 metres and the higher positional accuracy is of the  
order of 1 metre.

20       With track systems having covered track sections and  
relatively short track sections, requiring maximum  
continuity in establishing the position of the mobile units  
in the track system, each of the mobile units of the  
communication and positioning system according to the  
25       present invention includes dead reckoning means for  
determining the position of a respective mobile unit, and  
the communication and positioning system includes track  
identification means for identifying the covered track  
sections and shorter track sections and for initiating  
30       operation of the dead reckoning means. In operation, the  
dead reckoning function takes over the positioning function  
from preferably the last-obtained approved position  
calculated using the positioning equipment which operates

with totally open, or partially covered, or relatively long track sections. The system according to the present invention thereby operates with information about which track section or sections is/are the subject of a dead reckoning function or dead reckoning functions.

The dead reckoning means may include on-board transmission means and detection means for each of the mobile units, the transmission and detection means being spaced-apart along the length of a respective mobile unit. In addition, the dead reckoning means include a plurality of reflectors located on, and spaced-apart along the length of, a wall of the covered and shorter track sections. The distance between reflectors is preferably 1 metre. The transmission means may include a laser unit, in which case, the reflectors are passive light reflectors for reflecting a light beam emitted by the laser unit onto the detection means. For this arrangement, the detection means include a light pulse detector. The laser unit is adapted to continuously emit a light beam at least during passage of the respective mobile unit through the covered and shorter track sections.

According to a further aspect of the present invention, the communication and positioning system may include inertial navigation means for the dead reckoning means.

Thus, with the communication and positioning system according to the present invention, each of the base stations may include a radio communication system for communicating with each of the mobile units, and the on-board communication means for each of the mobile units may also include a radio communication system. The radio communication systems are preferably of a type known as

DECT (Digital European Cordless Telecommunications), and the DECT systems are adapted to provide data transmission between the base stations and mobile units, and a hand-over function to facilitate substantially uninterrupted data transmission between a mobile unit and a respective base station on passage of the mobile unit along the track system. The DECT systems may also include communication channels for the provision of public speech access and other services. In addition, the DECT system may include features, such as, general data transmission, good accessibility, flexibility, roaming, simplicity, and private operator structure. The telecommunication network for the system according to the present invention may, therefore, comprise a mobile radio network of the DECT type which offers public speech access on idle channels and the possibility for one, or more, additional facilities/services.

According to a further aspect of the present invention, a communication and positioning system is provided wherein the positioning function of the system is up-dated by means of the communication function of the system utilising the telecommunication means, the up-dating being effected by the reference positioning means, wherein the position of each of the mobile units is determined with an accuracy of approximately one metre, wherein the telecommunication means are used to inform a guidance system for the mobile units of at least the position and status of the mobile units, and wherein operation of the guidance system is effected via the telecommunication means on passage of a respective one of the mobile units passed one, or more, of the base stations. The telecommunication means are preferably of a type known as DECT (Digital European Cordless Telecommunications), and the up-dating of the positioning means is preferably effected by a fixed

calibrated Global Position System (GPS) reference station utilising corrections for differential GPS.

5 According to a further aspect of the present invention, a communication and positioning system is provided wherein each mobile unit includes an on-board guidance system, an on-board communication system, and an on-board positioning system.

10 According to a further aspect of the present invention, a communication and positioning system is provided wherein the base stations are each connected to, or form part of, a telecommunication network.

15 According to a further aspect of the present invention, a communication and positioning system is provided wherein the system includes central guidance means adapted to provide individual guidance for each of the mobile units in the track system and wherein the central guidance means is connected to the telecommunication means via which the on-board guidance means are up-dated.

20 The on-board guidance and positioning means of a mobile unit are preferably up-dated via the telecommunication means on passage of the mobile unit passed respective base stations and the base stations are preferably spaced-apart along the length of the track system at intervals of approximately 100 metres.

25 The mobile units may be provided by individual driverless carriages and the positioning of the mobile units is effected by means of mainly radio-based positioning tools which can be of a type known per se.

The foregoing and other features according to the

present invention will be better understood from the following description with reference to the accompanying drawings, in which:

5        Figure 1 illustrates, in the form of a block diagram, a communication and positioning system according to the present invention;

Figure 2 diagrammatically illustrates, in an essentially vertical cross-sectional view, a shallow tracked tunnel with openings for the ingress of light; and

10        Figure 3 diagrammatically illustrates, in a plan view, equipment for so-called dead reckoning means for determining the position of a mobile unit.

15        A communication and positioning system according to the present invention is illustrated in Figure 1 of the accompanying drawings, in the form of a block diagram, and includes a mobile unit (or carriage) 1 adapted for movement, in the direction of the arrows 2. The mobile unit 1 which may be track-bound, is intended to be driven in a track system (not illustrated) of a type known per se.

20        In practice, a transportation system would include a plurality of mobile units arranged to move along a track system. Thus, several mobile units 1 could be driven in the track system, at the same time, because accurate positioning and guidance can be effected by the present invention for each one of the mobile units in the track system. The spaced-apart base stations 6 and 7 are included in, or connected to, a fixed telephone network 8. The base stations 6 and 7, and the mobile unit 1 form part of a mobile radio network. The fixed telephone network 8 is connected to a central guidance system 9 and a reference

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equipment 10 for providing a reference for establishing the position of each of the mobile units in the track system. Also, a plurality of base stations would normally be provided and located at regular intervals along the length of the track system. In Figure 1, the mobile unit 1 is shown passing two of the plurality of base stations.

The mobile unit 1 comprises, or is provided with, an on-board guidance system 3, an on-board communication system 4, and an on-board positioning system 5. The communication system 4 is, in effect, a mobile communication system forming part of a mobile radio network which is preferably of the DECT (Digital European Cordless Telecommunications) type. The positioning system 5 is preferably of the GPS (Global Position System) type. The base stations 6 and 7 which also form part of the mobile radio network, preferable include a radio communication system of the DECT type.

The base stations 6 and 7 are arranged, for example, at approximately 100 metre intervals along the length of the track system. In operation, the mobile unit 1 passes each of the base stations 6 and 7, in turn, as it moves in the direction of the arrows 2 along a track. In Figure 1, the mobile unit 1 has passed base station 6 and is in communication with base station 7, as indicated by the reference 11. As previously stated, the base stations 6 and 7 are included in, or connected to, the fixed telephone network 8. Connected to the fixed telephone network, or telecommunication network, is the central guidance system 9 by means of which the mobile units 1 in the track system can be centrally guided. Guidance of the mobile units 1 is individual and communication from the central guidance system 9 to the on-board guidance system 3 is effected via the fixed telecommunication network 8. The reference

receiver 10 for the positioning function which is also connected to the fixed telecommunication network 8, preferably includes a calibrated Global Position System (GPS) reference station adapted to calculate corrections for differential GPS. The on-board positioning system 5 of the mobile unit 1 also preferably includes a mobile GPS receiver which is adapted to calculate the position of the mobile unit 1 in the track system. In operation, the position calculated by the on-board GPS receiver 5 of the mobile unit 1 is corrected by data from the fixed calibrated GPS reference station 10 to provide a higher positional accuracy than is attainable with the on-board GPS receiver 5 alone. Thus, the fixed calibrated GPS reference station 10 corrects the GPS equipment of the mobile unit 1 when it passes the base stations 6 and 7. Communication between a respective base station and the mobile unit 1 is, as stated above, represented by the reference 11.

The communication and position system illustrated in Figure 1 of the accompanying drawings represents a track system for collective traffic. The system can be applied to driverless rail traffic in densely populated areas with small carriages which run at relatively low speed, for example, a speed of 60 km/h, or more normally, 40 km/h and make frequent stops. A half-open environment, that is to say, an underground track system with admission of light and air, or a completely open environment, would probably be most usual in a future system of the type according to the present invention. Environmental and cost reasons point to this. Moreover, the GPS system requires that the proportion of wholly covered sections be limited along a respective track for the system to operate well. A solution based on DECT also gives, as an additional effect, the possibility of the communication and positioning system

to serve as an access network for public telephony in a collective traffic environment.

Figure 2 of the accompanying drawings diagrammatically illustrates, in an essentially vertical cross-sectional view, a shallow tracked tunnel 12 with openings for the ingress of light. This is a typical half-open environment for a transportation system in which a communication and positioning system, of the type according to the present invention, finds application. The tunnel 12 accommodates two carriages or trains 13 and 14 which are shown passing each other. The openness of the tunnel 12 is represented by a transparent roof 15 which provides access for the ingress of the rays of the sun and light 16. Thus, the communication and positioning system, illustrated in Figure 1 of the accompanying drawings, can be used for the transportation system illustrated in Figure 2, the positioning of the trains 13 and 14 preferably being affected using differential GPS.

Figure 3 of the accompanying drawings diagrammatically illustrates, in a plan view, equipment for so-called dead reckoning which is utilized in covered tunnels, or for short sections of track, requiring maximum continuity in establishing the position of the mobile units in the track system. With this arrangement, each of the mobile units includes dead reckoning means for determining the position of a respective mobile unit, and the communication and positioning system includes track identification means for identifying the covered track sections and shorter track sections, and for initiating operation of the dead reckoning equipment.

The dead reckoning equipment includes, as is illustrated in Figure 3, an on-board transmitter 18 and an

on-board detector 19 for the mobile unit 17. The transmitter 18 and detector 19 are spaced-apart along the length of the mobile unit 17. The dead reckoning equipment also includes a plurality of reflectors, three of which are  
5 illustrated and identified by the references 20 to 22, located on, and spaced-apart along the length of, a wall 20 of the covered and shorter track sections. The distance 'A' between the reflectors is preferably of the order of 1 metre.

10 Dead reckoning is a collective name for all methods which are used for determining position on the basis of a locally known position where different types of sensor, for example, sensors 20, 21 and 22, make it possible to  
15 calculate a movement. This provides very good precision initially, but the precision is progressively degraded. Due to the progressive degradation, the dead reckoning system must be upgraded, or calibrated, from the outside at regular intervals. A traditional and reliable method is  
20 inertial navigation (IN). Inertial navigation operates remarkably well for this application. A less expensive way is a combination of wheel sensors and a compass. However, locked wheels are normal in rail traffic, which is why such a method is not suitable in all possible cases.

25 The solution shown in Figure 3 provides a specially designated optical solution wherein the transmitter 18 is provided by a laser unit adapted to continuously emit a light beam, at least during passage of the mobile unit 17 through the covered and shorter track sections, and the  
30 reflectors 20 to 22 are passive light reflectors, for example, plastic reflectors, for reflecting the light beam onto the detector 19 which preferably includes a light pulse detector. The number of passes is calculated by the detector 19. As a result, it is known which reflector is

passed, and this provides the position (already measured earlier).

5       An advantage of the present invention is that the communication and positioning system provides a sufficiently good positioning accuracy for the mobile units through the use of differential GPS. Telecommunication networks of the DECT type, or similar systems, are suitable for data transmission in such systems. The basic functions are thus ensured. For the transmission of position data,  
10       networks of the GSM (Pan-European Cellular Digital System), NMT (Nordic Mobile Telephone System), MOBITECH type and even fixed networks, such as, PSTN (Public Switched Telephone Networks - Data Network) could be used in place of the DECT type networks.

15       The present invention is not restricted to the embodiments, shown by way of example above, but can be subjected to modifications within the scope of the subsequent claims and concept of the invention.

## CLAIMS

1. A communication and positioning system for use in a tracked transportation system having a plurality of mobile units arranged to move along a track system including a plurality of base stations located at regular intervals along the length of the track system and adapted to communicate with each of the mobile units; reference positioning means for providing a reference for establishing the position of each of the mobile units in the track system; on-board positioning means for each of the mobile units, adapted to establish the position of the respective mobile unit in the track system; on-board communication means for each of the mobile units, adapted to communicate with each of the base stations, on passage of the mobile unit past a respective base station; and telecommunication means for connecting each of the base stations to the reference positioning means, wherein the on-board positioning means of a mobile unit are up-dated by the reference positioning means when the mobile unit passes a respective base station, and wherein the said up-dating of the on-board positioning means is effected via the telecommunication means.

2. A communication and positioning system as claimed in claim 1 wherein the communication and positioning control functions are effected separately, wherein the communication function is effected via the base stations and wherein the positioning function is effected by a radio communication system.

3. A communication and positioning system as claimed in claim 1 or claim 2 for a track system including track sections in the form of at least partially open, or long,

track sections, wherein the reference positioning means includes a calibrated Global Position System (GPS) reference station adapted to calculate corrections for differential GPS, wherein the on-board positioning means of each of the mobile units include a mobile GPS receiver adapted to calculate the position of the respective mobile unit in the track system, and wherein the calculated position of a respective mobile unit is corrected by data from the fixed calibrated GPS reference station to provide a higher positional accuracy than is attainable with the on-board positioning means alone.

4. A communication and positioning system as claimed in claim 3 wherein the accuracy of the calculation of the position of a mobile unit by the on-board positioning means is of the order of 100 metres and wherein the higher positional accuracy is of the order of 1 metre.

5. A communication and positioning system as claimed in any one of the claims 1 to 3 for covered track sections and shorter track sections, requiring maximum continuity in establishing the position of the mobile units in the track system, wherein each of the mobile units includes dead reckoning means for determining the position of a respective mobile unit, and wherein the communication and positioning system includes track identification means for identifying the covered track sections and shorter track sections, and for initiating operation of the dead reckoning means.

6. A communication and positioning system as claimed in claim 5 wherein the dead reckoning means includes on-board transmission means and detection means for each of the mobile units, the transmission and detection means being spaced-apart along the length of a respective mobile unit;

and a plurality of reflectors located on, and spaced-apart along the length of, a wall of the covered and shorter track sections.

5 7. A communication and positioning system as claimed in claim 6 wherein the distance between reflectors is 1 metre.

10 8. A communication and positioning system as claimed in claim 6 or claim 7 wherein the transmission means includes a laser unit adapted to continuously emit a light beam, at least during passage of the respective mobile unit through the covered and shorter track sections, wherein the reflectors are passive light reflectors for reflecting the light beam onto the detection means, and wherein the detection means include a light pulse detector.

15 9. A communication and positioning system as claimed in any one of the claims 5 to 8 wherein the communication and positioning system further includes inertial navigation means for the dead reckoning means.

20 10. A communication and positioning system as claimed in any one of the preceding claims wherein each of the base stations includes a radio communication system for communicating with each of the mobile units, and wherein the on-board communication means for each of the mobile units includes a radio communication system.

25 11. A communication and positioning system as claimed in claim 10 wherein the radio communication systems are of a type known as DECT (Digital European Cordless Telecommunications), wherein the DECT systems are adapted to provide data transmission between the base stations and mobile units, and wherein the DECT system is adapted to  
30 provide a hand-over function to facilitate substantially

uninterrupted data transmission between a mobile unit and a respective base station on passage of the mobile unit along the track system.

5 12. A communication and positioning system as claimed in claim 11 wherein the DECT systems includes communication channels for the provision of public speech access and other services.

10 13. A communication and positioning system as claimed in claim 10 wherein the radio communication systems are of a type known as DECT (Digital European Cordless Telecommunications), and wherein the DECT systems includes communication channels for the provision of public speech access and other services.

15 14. A communication and positioning system as claimed in claim 1 wherein the positioning function of the system is up-dated by means of the communication function of the system utilising the telecommunication means, the up-dating being effected by the reference positioning means, wherein the position of each of the mobile units is determined with  
20 an accuracy of approximately one metre, wherein the telecommunication means are used to inform a guidance system for the mobile units of at least the position and status of the mobile units, and wherein operation of the guidance system is effected via the telecommunication means  
25 on passage of a respective one of the mobile units passed one, or more, of the base stations.

30 15. A communication and positioning system as claimed in claim 14 wherein the telecommunication means are of a type known as DECT (Digital European Cordless Telecommunications), and wherein the up-dating of the positioning means is effected by a fixed calibrated Global

Position System (GPS) reference station utilising corrections for differential GPS.

5 16. A communication and positioning system as claimed in any one of the preceding claims wherein each mobile unit includes an on-board guidance system, an on-board communication system, and an on-board positioning system.

10 17. A communication and positioning system as claimed in any one of the preceding claims wherein the base stations are each connected to, or form part of, a telecommunication network.

15 18. A communication and positioning system as claimed in any one of the preceding claims wherein the system includes central guidance means adapted to provide individual guidance for each of the mobile units in the track system and wherein the central guidance means is connected to the telecommunication means via which the on-board guidance means are up-dated.

20 19. A communication and positioning system as claimed in claim 18 when appended to either claim 16, or claim 17 wherein the on-board guidance and positioning means of a mobile unit are up-dated via the telecommunication means on passage of the mobile unit passed respective base stations.

25 20. A communication and positioning system as claimed in any one of the preceding claims wherein the mobile units are individual driverless carriages.

30 21. A communication and positioning system as claimed in any one of the preceding claims wherein the base stations are spaced-apart along the length of the track system at intervals of approximately 100 metres.

22. A communication and positioning system for mobile units in a track system substantially as hereinbefore described with reference to the accompanying drawings.

5 23. A transportation system including a communication and positioning system as claimed in any one of the preceding claims.

**Relevant Technical Fields**

(i) UK Cl (Ed.N) H4D (DPBC, DAA, DAB, DLAA, DLAB, DBR, DPDX, DPBX, DPX) H4L (LDSL, LDLX)

(ii) Int Cl (Ed.6) G01S, B61L

Search Examiner  
 DR E P PLUMMER

Date of completion of Search  
 23 JANUARY 1995

**Databases (see below)**

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

Documents considered relevant following a search in respect of Claims :-  
 ALL

(ii)

**Categories of documents**

- |   |   |
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| <b>A:</b> Document indicating technological background and/or state of the art.   | <b>&amp;:</b> Member of the same patent family; corresponding document.   |

Category	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2264837 A (KOKUSAI DENSHIN DENWA) eg. abstract, Figure 5	
A	EP 0199266 A (SIEMENS) whole document	
A	US 4209749 (SIEMENS) eg. abstract, Figure 1	
A	US 3808426 (BRITISH RAILWAYS) eg. abstract, Figure 1, Figure 3	

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